The Iowa River Bridge – Pushing the Limits

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ABSTRACT: The construction of the first incrementally-launched I-girder highway bridge in the United States has recently been completed. The focus of this paper will be to present the construction of this unique bridge including: original design considerations, contractors' launching system design, consultant erection system review and launching process. Bridge instrumentation, including strain gauges and tilt meters was installed to monitor the bridge during launching operations.

Project Overview

The existing U.S. Highway 20 was constructed in the 1920's as one of the main east-west roadways across northern Iowa. Beginning in 1967, the Iowa Department of Transportation (IaDOT) has been replacing the existing two-lane road with a limited access four lane highway. The primary impediment to completing this improvement was finding a way to cross the Iowa River Greenbelt, a very environmentally sensitive area. The recently completed U.S. Highway 20 bridge over the Iowa River marks the culmination of nearly 35 years of environmental studies, engineering design and construction.

The incremental launching technique was developed by Leonhardt[1] in the early 1960's for use with precast concrete box girder bridges. More than 250 of these bridges have been completed in Europe.

The incremental launching method offers a number of benefits to the owner and the contractor:

- Minimal disturbance to surrounding area
- Smaller, but more concentrated area required for erection
- Additional worker safety since all erection work is performed at lower elevation

The steps in the incremental launching process used on the Iowa River Bridge (IRB) consist of:

- Erect all of the structural steel for the first 154 m of the eastbound bridge (including four girder lines, diaphragms and upper and lower lateral bracing) on temporary pile bents behind the east abutment.
- Attach launching nose (leading end) and tail section (trailing end) to girder train.
- Jack the girder train forward longitudinally 92 m from Pier 6 to Pier 5.
- Remove tail section, splice additional girder sections to the tail end of the girder train.
- Reinstall tail section.
- Repeat sequence for a total of five spans.

The entire eastbound steel unit bridge was launched first. Following that, the temporary pile bents were removed and reinstalled for use in launching the westbound steel unit.

Environmental Considerations

The selection of the incremental launching method was made to minimize disturbance of the environmentally sensitive Iowa River Greenbelt. The Greenbelt is one of the few remaining areas of old-growth timbers in central Iowa, and as such, was vitally important to conservationists.

There are a number of environmental issues that were considered in the design and construction of the bridge. They include:

- Fresh water mussels that inhabit the Iowa River

- Bald eagle roosting area adjacent to the bridge
- Native American ancient campsites in area
- Endangered Northern Monkshood plant

The Iowa River is the preferred habitat of at least three rare species of freshwater mussel. These mussels are very sensitive to changes in the temperature and clarity of the river. For this reason, very strict environmental limitations were included in the contract documents. The use of causeways or temporary bridges to cross the river were prohibited and the contractor was required to provide containment for all equipment and remove all drilling spoils, including artesian water, from the contractually defined Environmentally Sensitive Work Zone (ESWZ).

A small valley near the bridge site has fairly steep slopes and is oriented nearly east-west. This configuration tends to shelter the valley from the coldest northwest winds and snow in the winter. Combined with the small dam and open water just downstream, the valley makes roosting habitat for bald eagles. The contract provided for monitoring of the bald eagle behavior during winter months, and if disturbance of the eagles was observed, construction work could be suspended for several months.

This shelter was recognized by the Native Americans who inhabited the area hundreds of years ago. A number of ancient campsites and associated artifacts were discovered near the bridge site during the environmental study phase of the project. In addition, the Northern Monkshood plant, a federally protected poisonous herb, exists in the river valley. The alignment of the highway was adjusted to minimize interference with sensitive areas.

Construction activities in the ESWZ were specifically defined in the contract plans. A total of six different zones were identified in the plans that required different methods for clearing existing trees and grubbing undergrowth.

Preliminary Design

An interesting piece of history involves the Iowa River itself. During the mid-19th century, at least three separate gold discoveries were reported along the Iowa River near the bridge site. Although very few of the prospectors that flocked to the area found significant amounts of gold, they did help to spur the growth of the nearby town of Steamboat Rock.

HNTB was hired by the IaDOT in 1994 to perform the preliminary design of a bridge across the Iowa River. During this phase, a number of different bridge types were evaluated including:

- Steel deck arch
- Continuous steel truss
- Precast concrete segmental
- Steel box girders
- Steel I-girders

The selection of the preferred alternate was not based strictly on construction cost, but on aesthetics as well. The IaDOT wanted a low-profile structure to minimize the visual impact on this scenic area. The final selection of a steel I-girder bridge was made in 1996. The incremental launching method was the only feasible way to construct a bridge while minimizing impact to the environmentally sensitive valley.

Bridge Description

The bridge consists of two parallel deck superstructures, each containing five equal spans of 92 meters. A 19 m prestressed concrete jump span is provided on each end of the steel unit. The I-girders were fabricated from ASTM A709 Grade 345 weathering steel. The girders are 3450 mm deep and spaced at 3600 mm centers. The web depth was not chosen based on strength requirements, but rather to reduce the dead load deflection during the cantilever launching phase to a reasonable level. Because any point along the girder length could become a bearing location during launching operations, the webs were designed thick enough to serve as an unstiffened element for steel dead load.

The concrete deck consists of a 230 mm concrete slab with a 38 mm low-slump concrete wearing surface. A high performance concrete (HPC) mix was used for the deck in order to minimize the potential for shrinkage and positive moment deck cracking.

The foundations of the bridge are 890 kN steel H-pile foundations driven to rock at Piers 1, 2 and 5 and 890 kN steel H-piles driven to refusal in clay at Pier 6. In order to minimize the footprint of the pier foundations near the river, Piers 3 and 4 are founded on 2440 mm diameter drilled shafts approximately 30 m deep.

The subsurface material at the bridge site consists of approximately 20 m of glacial clay material overlying medium hard limestone. Borings at the site indicated an artesian water condition in a thin layer of fine sand just above the limestone layer. This water was considered unsuitable for disposal in the river, due to presence of the freshwater mussels. The contractor was required to collect the water generated by the drilling operations and dispose of the water at an approved offsite location.

The soil material is very prone to erosion and shallow slope failures. The original design of the bridge did not include the concrete jump spans on each end of the steel unit. However, the IaDOT did not feel comfortable with a condition that would require the abutments at the end of the steel unit to resist the horizontal earth pressure that a slope failure could apply to the backwall. Instead, a more typical integral abutment was added at the end of the jump span and the depth of fill behind the shorter end pier was considerably reduced.

A “belt-and-suspenders” approach was used for the design of the concrete piers. The piers were designed to resist the earth pressure that would result from a potential slope failure. In addition, a three-sided wall of slope protection piles, consisting of HP310x79 piles driven at 380 mm centers, was constructed surrounding the footing locations at Piers 1, 2, 5 and 6.

Launching System

HNTB developed a conceptual launching system for the bridge that was illustrated in the contract plans. This system was modified to suit the contractor’s equipment by the erection engineer, Ashton Engineering of Davenport, IA.

A launching pit was excavated behind the east end of the steel girder unit exclusively for the erection and launching of the steel girder spans. The pit was approximately 200 m long x 36 m wide x 6 m deep. This launching pit presented a significant concern from an environmental standpoint. The contractor was required to confine all stormwater and direct it to three intakes in the center of the launching pit.

A series of seven temporary pile bents were constructed in the launching pit. Five of these bents were equipped with vertical and horizontal rollers to support and guide the girders during launching operations (Fig. 1), while two bents were used to provide support only during steel assembly. A vertical bearing roller beneath the bottom flange of each girder was used to support the mass of each girder line and a pair of horizontal guide rollers was used to provide alignment control at each bent. The guide rollers were positioned to roll against the edge of the bottom flange. The same type of rollers was installed on the top of each permanent concrete pier.

Fig. 1 Rollers support girders and provide alignment control

The guide rollers were equipped with a 450 kN hydraulic jack to apply a transverse force against the girder bottom flange during launching. By actively controlling the hydraulic pressure in these jacks, the contractor was able to provide steering control of the girders.

The structural steel was completely erected on the temporary roller bents. All bolts were properly tightened and a bridge drainage piping system was installed prior to launching the girder train. This drainage system was required to prevent any storm water or runoff from entering the river.

The incremental launching technique was developed for very stiff concrete box girders. In order for the steel I-girders on the IRB to act as torsionally rigid as possible, the center bay of each superstructure was provided with a very stiff "spine" of upper and lower lateral bracing (see Figure 2).

This stiff "spine" created a unique concern following the launching of the steel girder units. When the girders reached their final position and were jacked down, they did not fully bear on the permanent bearings. In some cases, a gap of up to 12 mm was observed between the bearing and the bottom flange. These gap locations were fitted with a shim to not only fill the gap, but to preload the bearing so that all girder reactions were uniform at a given pier.

Fig. 2 Launching pit and steel assembly behind east abutment.

The leading end of the steel girder unit was equipped with a tapered launching nose (Fig. 3). The nose consisted of a pair of tapered I-girders bolted to the leading end of the permanent interior girders. The nose was approximately 44.6 meters long and tapered from 3450 mm deep at the connection to the permanent girders to 1200 mm deep at the tip. The nose served two purposes – reduce the weight of the cantilever span during launching and provide a method to "recover" the leading end of the girders as they approached each pier. The calculated deflection during the maximum cantilever stage of the bridge was 2150 mm.

The trailing end of the steel unit (Fig. 4) was equipped with an 8380 mm long tail section. The tail section consisted of a four girder assembly bolted to the trailing end of the girder train. The trailing end of the tail section provided a dapped seat 1525 mm wide and 2030 mm deep. The tail also served two purposes – provide a location to apply the jacking force to the rear of the girder lines and the tapered shape (6:1 ratio) provided a smooth transition as the trailing end of the girders "dropped off" the roller supports in the pit as the girders were launched forward. The dapped end of the tail supported a transverse tugger beam – two W920x223 sections welded tip-to-tip with 63 mm cover plates.

The jacking system used to launch the steel unit was supported by two groups of battered steel H-piles located near the east end of the launching pit. Each pile group supported a 1350 kN capacity hydraulic ram which was oriented parallel and adjacent to the exterior girder.

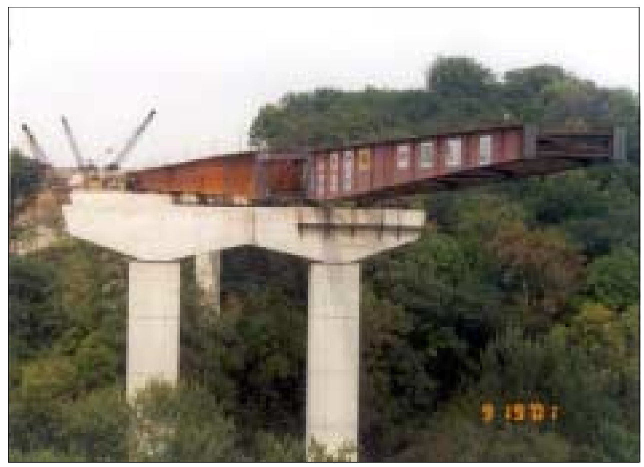

Fig. 3 Tapered launching nose at leading end of girder train

Each hydraulic jack was attached to a line of 64 mm diameter, 1035 MPa post-tensioning bars. These bars were spliced at 4.6 m intervals. The dead end of the bar was anchored to a transverse tugger beam that was supported on the dapped end of the tail section at the trailing end of the girders. When the jacks were engaged, the threadbars were advanced longitudinally at approximately 0.3 m per minute. A section of threadbar was removed from each jack unit following a 4.6 m stroke by the jacks.

In order for the bolted girder splices to negotiate the bearing rollers, a tapered (6:1 ratio) ramp plate was installed at the leading and trailing end of each splice. During launch operations, each time a ramp plate would encounter a roller, a measurable increase in jacking force was observed. This additional energy was released as a girder "lunge" as the ramp plate was cleared and the rollers returned to the flat region of the flange.

Fig. 4 Jacking system including tapered tail section and 64 mm threadbars

Launch operations were not permitted to proceed if wind speeds in excess of 32 km/hr were anticipated within a 12 hour period. Two different launch events were postponed due to this restriction. The steel girders were launched in one span increments in order to minimize the exposure time of the free cantilever.

Launching Instrumentation

The Iowa DOT contracted with researchers at Iowa State University, led by Drs. Terry Wipf and Brent Phares, to install instrumentation and monitor strains and deflections during launch operations.

Strain gauges were installed on the following elements of the bridge:

- Girder webs and flanges
- Bearing rollers
- Girder diaphragms
- Jacking threadbars

The jacking force required to launch the bridge was monitored in two ways. First, the hydraulic pressure in the calibrated jacking system was continuously monitored during all launch events. In addition, the jacking force applied to the girders was directly recorded via a load cell attached to each line of threadbars. A measurable difference (10-15%) in jacking force was recorded from the north jack unit to the south jack unit. This difference did not appear to have any significant impact on the transverse alignment of the girders during launching.

The concrete piers were monitored for horizontal movement and rotation using a series of string potentiometers and tilt meters. It should be noted that construction personnel observing from the top of the pier reported a considerable “rebound” effect each time a transverse line of girder ramp plate passed over the bearing rollers on a pier.

The final results of these instrumentation studies will be presented in a formal report to the Iowa DOT in mid-2003.

Construction Timeline

The ten launches of the IRB were performed at approximately 2-3 week intervals between August, 2001 and March, 2002. Following the completing of the eastbound bridge launching in October, 2001, the contractor removed all of the temporary pile bents in the launching pit. These pile bents were reinstalled for use in launching the westbound bridge starting in January, 2002.

The launching rollers were removed when the girders reached their final horizontal position. The mass of the girders was lifted just enough to unload the rollers using a 1780 kN jack at each girder location, the rollers were slid out from beneath the girders and the permanent pot bearings were slid into position. The jacks had a very small range of motion, so the girders were lowered in approximately 25 mm increments using a series of shim packs. This jacking operation was started at one end of the steel unit and continued in sequence to avoid overloading the jack units.

Summary

The U.S. 20 Iowa River Bridge is the first launched, I-girder highway bridge constructed in the United States. It is the culmination of over 35 years of environmental studies, engineering design and construction.

This project is proof that the incremental launching technique can be successfully performed on longer span steel I-girder bridges. It is anticipated that this method of construction will become more commonplace in the U.S. as bridge owners recognize the potential benefits. This technique is applicable to either environmentally sensitive areas or locations limited by restricted access.

References

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